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Biogas from beet pulp
Energy production and Greenhouse Gas Reduction

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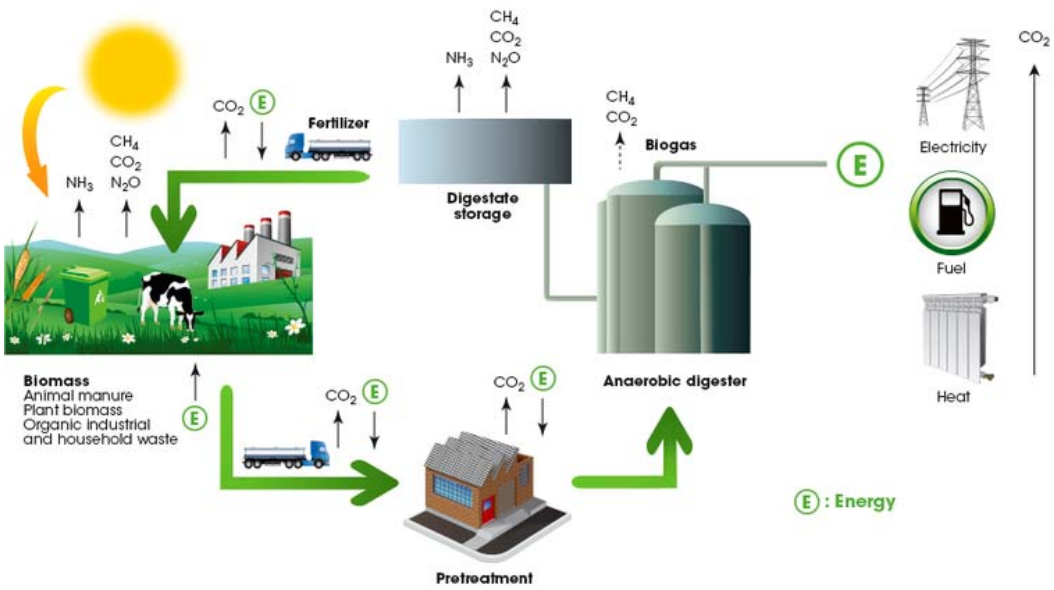
OBJECTIVE AND RESULT

Objective

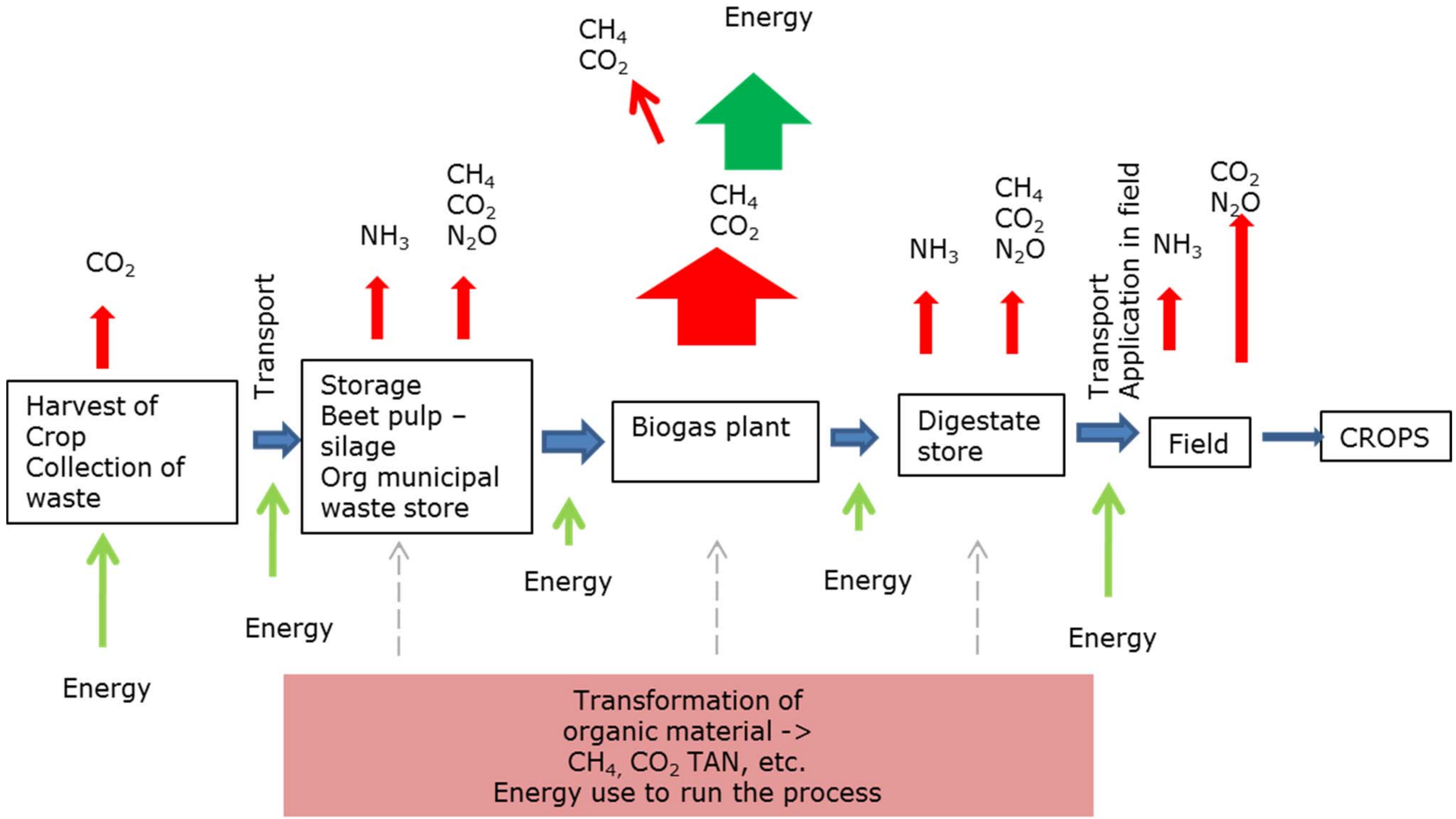
Develop model integrating **value** chain and **biogas** and **environmental** models.

Result

Decision support for biogas plant management and regional/national decision making.



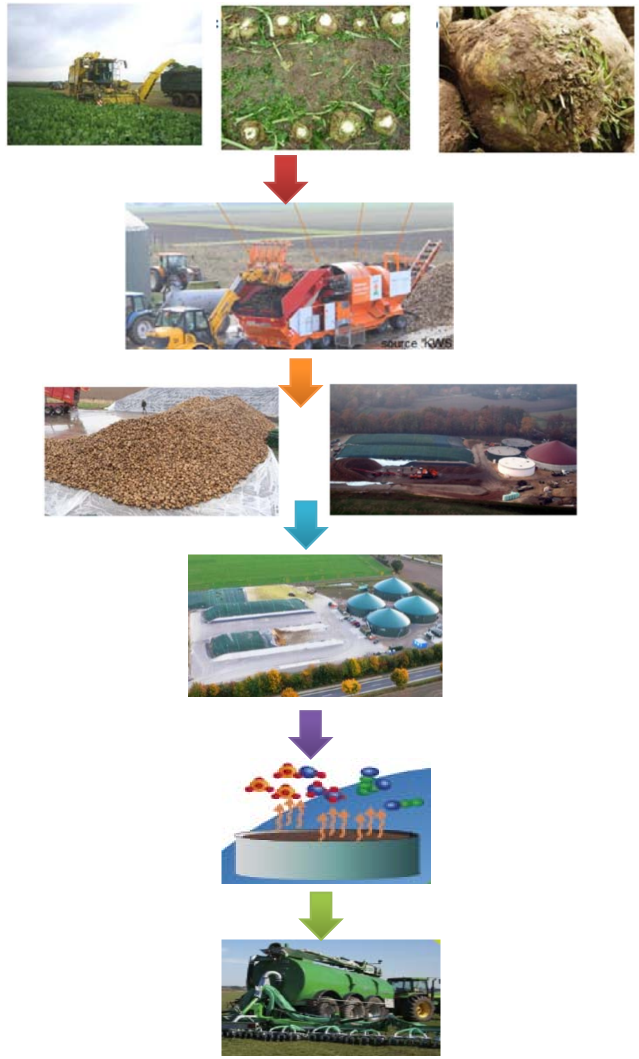
Conceptual model of biogas production and greenhouse gas emission



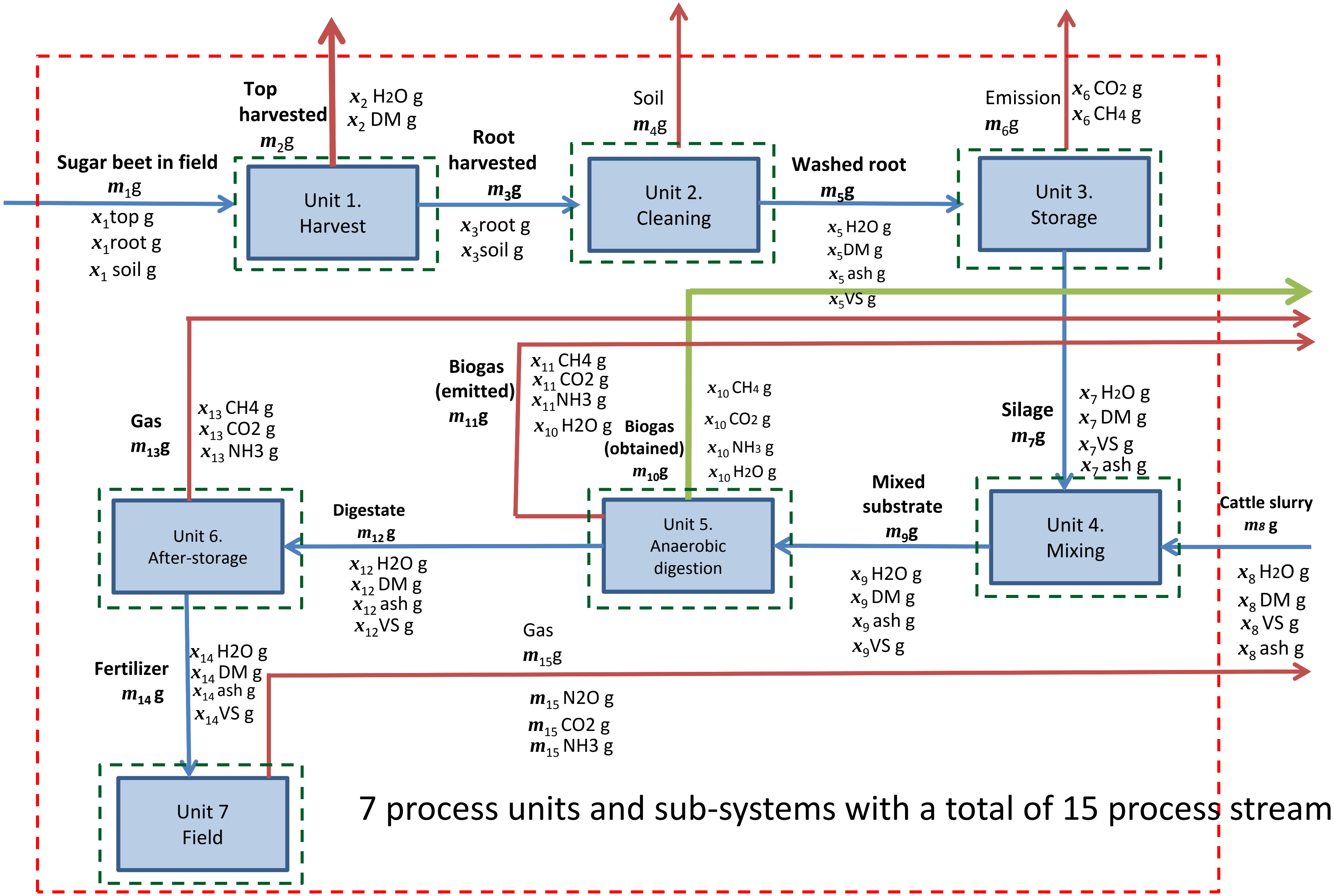
Process Description

Biogas production of sugar beet in Energy production and Greenhouse Gas Reduction

Harvest in October o Beet top for animal feed o Beet root for bigas production	Harvest
Dry Cleaning in the field o Removing soil, sand, stones, etc.	Cleaning
Ensilage for 8 months o Whole beet root, fermentation o Covered	Ensilage
Co-digestion with cattle manure 1200m3, 6ton/day, 37°C, HRT 20days	Cattle manure → Biogas production
PVC roof (avoid dilution), until field application	Post -storage
Applied in October or April	Field

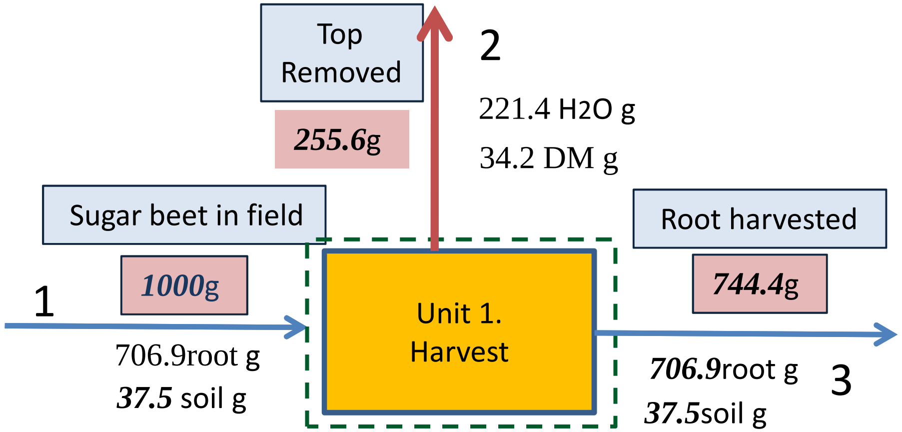


System Analysis - Flow chart of Reference Scenario



7 process units and sub-systems with a total of 15 process streams

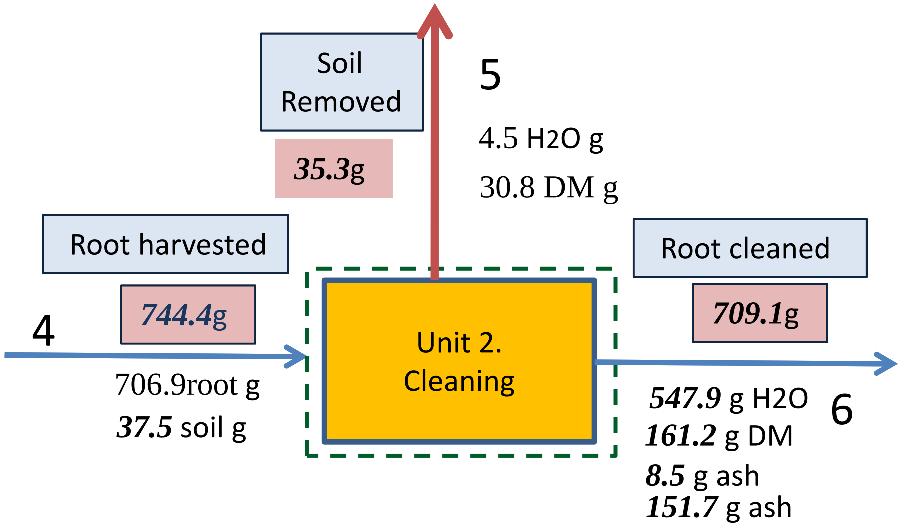
Process unit 1. Harvest



- Top for animal feed
- Root for biogas production
- Soil : 22% of beet's dry matter

Composition of root +soil (stream 3)

Process unit 2. Cleaning



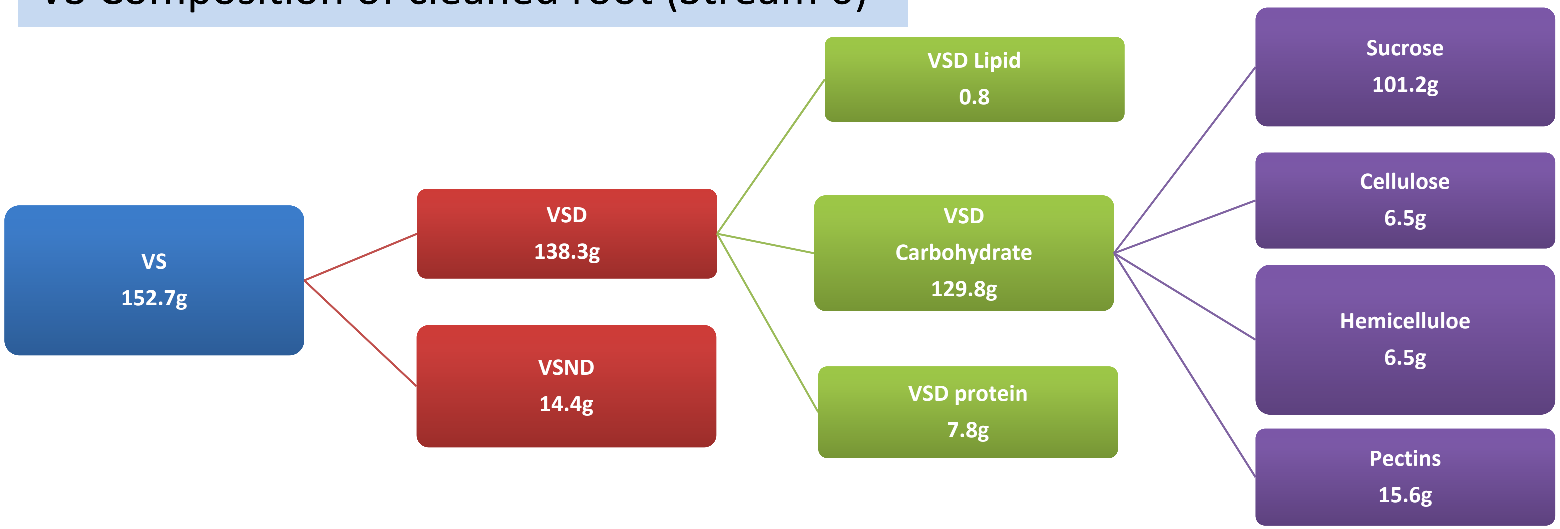
Cleaned root

AgroTech (Jørgen Pedersen)

Soil residue

- 3.4% (dry cleaning)
- 2.1% (wet washing)

VS Composition of cleaned root (Stream 6)



Process unit 3. Ensilage

- GHG emission
  - CH_4 emission during first period (2-3 weeks)

- VS change
  - German study (Weißbach *et al.*, 2009) :16%
  - Our study : 27.4(2.0%)

- BMP change
  - Increasing of BMP per VS
  - Slight decreasing of BMP per total wet weight

- German study (Weißbach et al., 2011)

Beet type	BMP (L/kg VS)	BMP (L per kg fresh beet)
Fresh beet	361	83
SIlage	383	81

- Our study

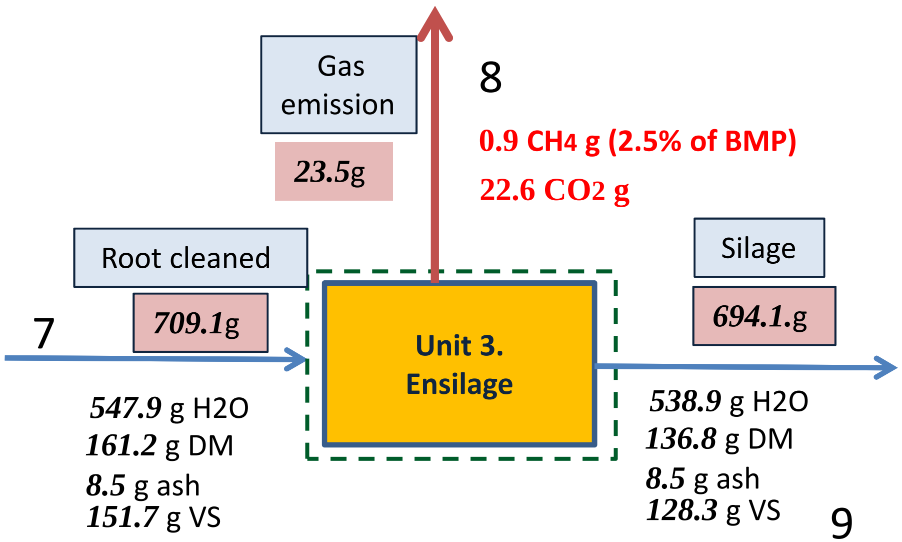
Beet type	BMP (L/kg VS)	BMP (L per kg fresh beet)
Fresh beet	324	70
Silage	359	67

- TBMP of sucrose and ethanol

	TBMP per kg VS		**Before Ensilage**	**After ensilage**
	CH_4 NL kg VS^{-1}	CO_2 NL kg VS^{-1}	g	g
Sucrose	**393**	393	101 →	31
Ethanol	**730**	244	0 →	21

Process unit 3. Ensilage

Mass balance flow chart of Ensilage



- **Well fermented root silage**

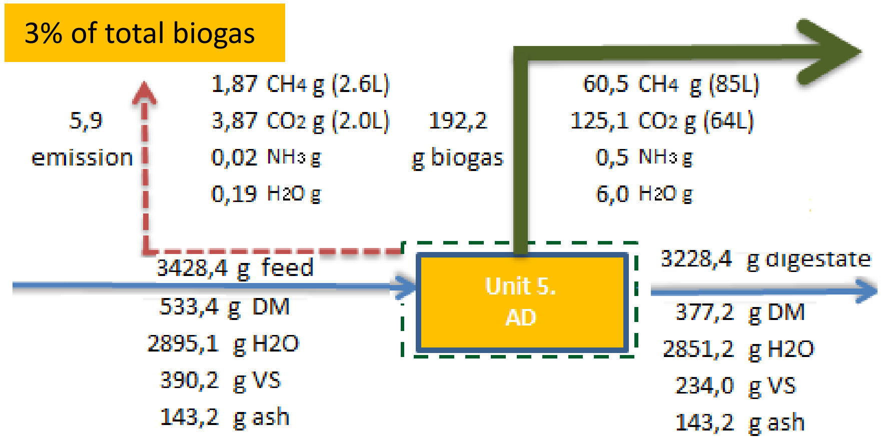
AgroTech (Jørgen Pedersen)

- VS destruction : Great dependency of ensilage duration

	Before ensilage	Fraction (%) Up to 6 months	More than 6 months
Sucrose	78	60	30
Glucose	0	6	8
Ethanol	0	10	20
Hexoses	5	7	9
Pentose	5	7	9
Pectins	12	10	24
Total	100	100	

- Methane potential less affected due to alcoholisation of carbohydrate
- CO_2 gas emission from fermentation (CO_2 neutral)
- Lack of data for modelling

Process unit 5. Biogas production



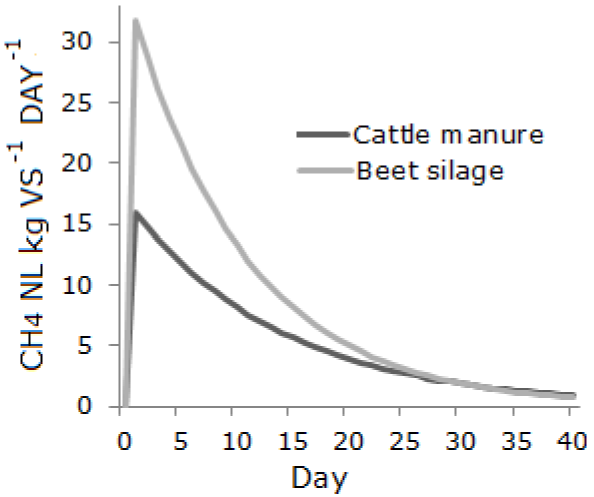
44L CH_4 from cattle manure

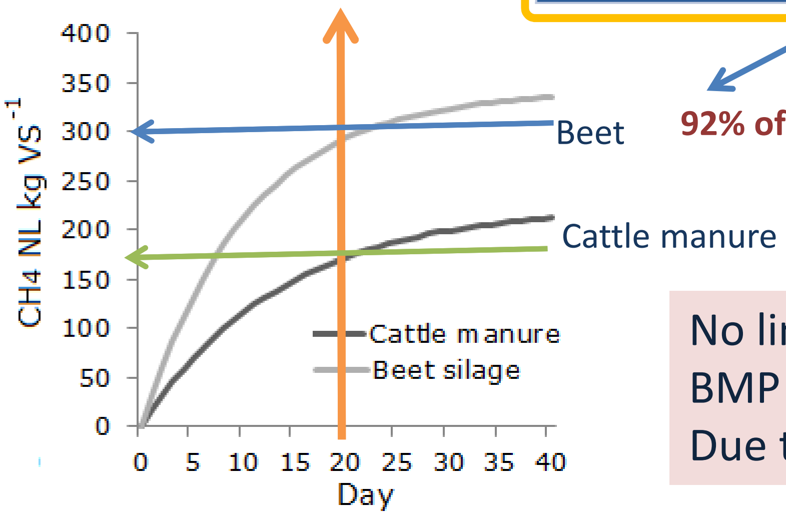
42L CH_4 From Beet root

VS destruction

	Beet	Manure
Input VS g	128	261
Removed VS g	90	66
Remaining VS g	39	196
VS destruction%	70	25

- Methane production rate and cumulative yield



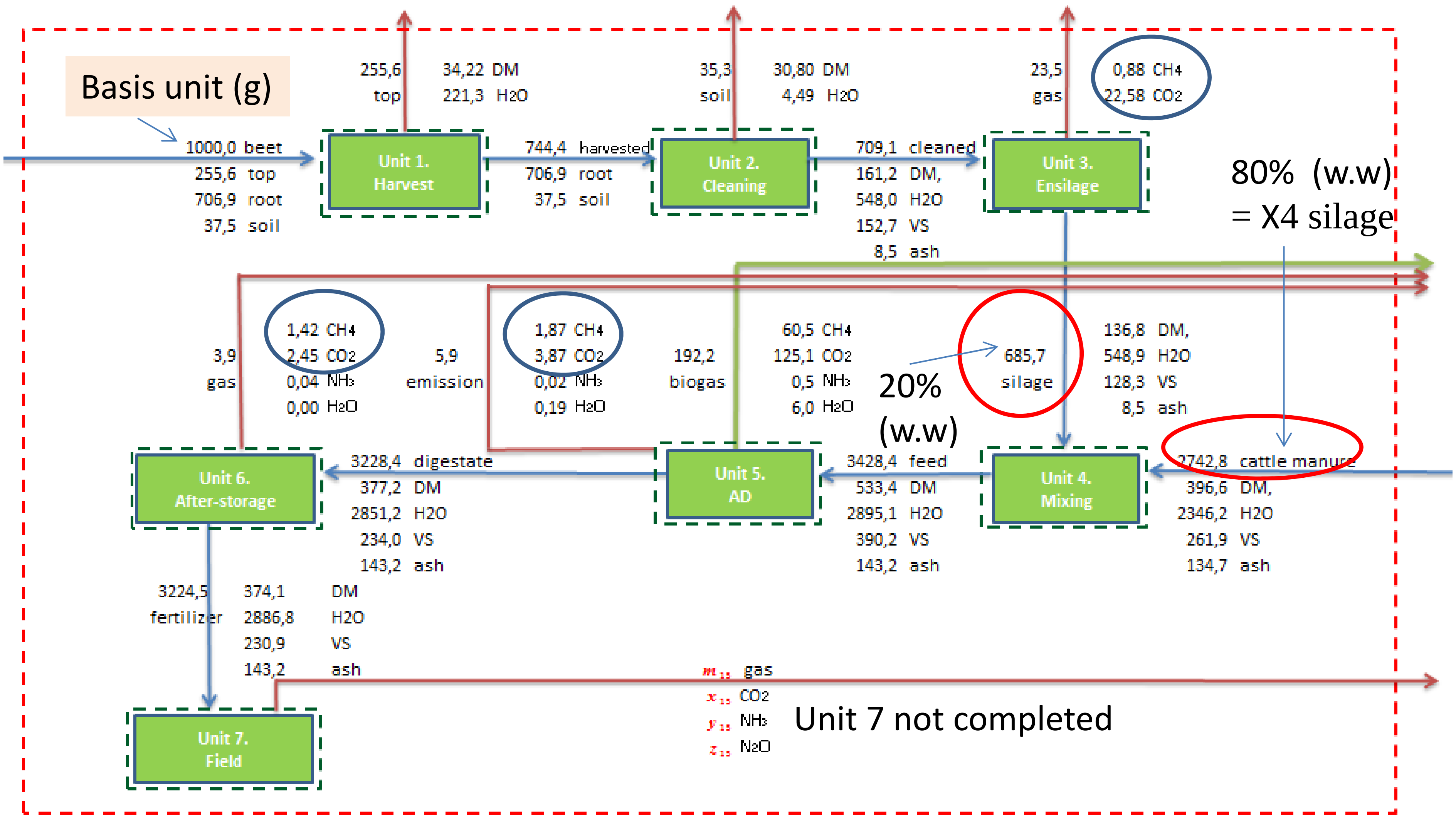


92% of BMP removed

85% of BMP removed

No linear relation between BMP and VS destruction
Due to different digestibility

Overview of model
(1000 g of beet + 2700 g cattle manure)



Scaling up model (Annual beet harvested ton per ha)

Scaling

- Changing values of all amounts or flow rates by proportional amount.
- Compositions remain unchanged.

Scale factor = Desired basis / Reference basis

$$\frac{123 \text{ton ha}^{-1} \text{yr}^{-1}}{1000 \text{g}}$$

0.123 (ton ha^{-1} yr^{-1} g^{-1})

Basis of reference model (1000g beet)

X (S.F)0.123 (ton ha^{-1} yr^{-1} g^{-1})
S.F multiplying flow rate of all the stream (not fraction)

Basis of up-scaled model = 0.123 (ton ha^{-1} yr^{-1})

Energy production

Basic Model

(beet 1000g +2742g cattle manure)

Biogas

- CH_4 60.5g (84.7L)
- CO_2 125.1g(63.7L)
- Total: 185.6g(148.4L)

Energy

- 3.4MJ

Electricity

- 0.95Kwh

Upscaled Model

(beet harvested ton **ha^{-1} yr^{-1}** + cattle manure)

Biogas

- CH_4 : 8.4.Mg (11780 m3)
- CO_2 : 17.4Mg (8855 m3)
- Total: 25.4Mg (20634m3)
- 43m3/ton

Energy

- 474588MJul
- 941MJ/ton

Electricity

- 131Mwh (261Kwh/ton)

GHG emission using biogas technology (Reference Model)

SGS1 SG

With Biogas production (Beet + manure)

- CH_4 : 4.177g (0.88g ensilage, 1.87g biogas plant emission, 1.42g after-storage)
- CO_2 : 7.289g
- GHG as CO_2 eq. : 111.7 g

Without biogas production (manure)

- CH_4 : 4.183g , CO_2 : 7.3g , GHG as CO_2 eq. : 111.9g

No GHG reduction, may be due to :

- GHG emission from beet silage included
- CH_4 emission from ensilage
- Emission from a biogas plant

Slide 14

SGS1 Include (Beet and slurry)
Sven G. Sommer; 16-09-2013

SGS2 include (Slurry)
Sven G. Sommer; 16-09-2013

Improvement of current method to determine GHG emission during storage of digestate

IPCC (2006) methodology

- CH_4 [kg] = VS [kg] * BMP[$m^3 CH_4$ per kg VS]*MCF*0.67 [kg CH_4 per m^3 CH_4]
- (*IPCC choose to use BMP of fresh slurry from animal house*)
- **1.07 CH_4 [kg]/ [kg]** = ((0.27VS [kg] *0.224[m^3 CH_4 per kg VS](BMP of fresh slurry) * 0.67[kg CH_4 per $m^3 CH_4$] * 0.1(MCF))/2.7kg

Method used for our study

- After biogas production the BMP of the digestate is quite lower than BMP of fresh slurry. BMP of digestate is applied. *Reduced BMP must be applied!*
- **0.25 CH_4 [kg]/ [kg]** = ((0.27VS [kg] *0.051[m^3 CH_4 per kg VS](BMP of fresh slurry) * 0.67[kg CH_4 per m^3 CH_4] * 0.1(MCF))/2.7kg

Risk of over estimation of GHG emission using IPCC current protocol in biogas scenario

Our experiments on BMP of digestate from full scale biogas plant (7samples)
(0.086 (±0.19) **m^3** CH_4 per kg VS)

Conclusion and Perspective

- **New knowledge need**
  - BMP of biomass for digester not linear related to VS
- **End user need**
  - Outcome of the decision support tool?
  - Information for the model in general available by the end user?
- **Demand to the analytical tool**
  - Which characteristics
  - Cost (investment & running cost)